Quarterly Report
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I. Near-term Objectives

Refine and extend the retrieval algorithm developed by Nakajima and King for determining the cloud optical thickness and effective radius of clouds from reflected solar radiation measurements. This program has thus far been applied to 2 channels of the MAS (MODIS Airborne Simulator), but will in the future be extended to multiple wavelengths appropriate for MODIS. Work has recently been conducted and will be continued on the studies of including Rayleigh scattering correction, aerosol scattering correction and geometry correction. A reduction of angular information, which were stored in the codes and required by the retrieval algorithm, should be sought in order to increase the capacity of containing multi-spectral information.

II. Task Progress

a. MODIS-related Field Experiments

Michael King, Tom Arnold, Liam Gumley and Si-Chee Tsay spent nearly a month of their time participating in two field experiments, as described below.

1. TOGA / COARE experiment

I participated in the Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment (TOGA / COARE), based in Townsville, Australia, between February 14 and 28. One of the major TOGA / COARE objectives was to improve our understanding of the role of the western Pacific Ocean warm pool in the mean and transient state of the tropical ocean / global atmosphere system. The TOGA / COARE consisted of numerous coordinated research flights over convective clouds in the intensive flux array, with the NASA ER-2 and DC-8 aircraft playing the remote sensing role and the NOAA P-3s and NCAR Electra the in situ and boundary layer roles. Much of my interest in this experiment focused on obtaining high quality multispectral imagery from the MAS, mounted on the ER-2 aircraft. I was especially interested in acquiring observations of high altitude cirrus clouds. It was my main interest to coordinate these high altitude (ER-2) remote sensing measurements with nearly simultaneous in situ microphysical measurements obtained from the DC-8. I was further interested in mapping the cloud boundaries, especially if multilayered clouds were present, using nadir propagating lidar from the ER-2 (to map cloud top boundaries), and zenith propagating lidar measurements from the DC-8 (to map cloud base altitude and structure). During the entire 6 weeks that the NASA aircraft participated in COARE, 13 research flights were conducted with the DC-8 aircraft, 11 of which were coordinated with the ER-2. I was the flight scientist for the NASA ER-2 aircraft for one of these flights, and mission scientist for the DC-8 coordinating the overall mission (February 24). Highlights of this flight are as follows:

o Coordinated flight between the ER-2 and DC-8 over the ground site at Kavieng, Papua New Guinea, consisting of 5 overflights of the ground site.

o The ER-2 flew 150 km legs perpendicular (2.5 legs) and parallel (2.5 legs) to the plane of the sun.

o The DC-8 flew one leg within the cirrus clouds (to measure microphysics) and one leg below (to map cloud base altitude using the zenith propagating lidar), for each 150 km leg parallel and perpendicular to the sun.

o The cirrus consisted of many levels, and was composed of hexagonal crystals, as evidenced by a 22 degree halo, sun dogs, and a sun pillar. The lower-layer water cloud often showed a glory as well.

o The MAS imagery showed the glory from the lower level water clouds quite well in the visible channels, since those channels saw through the semi-transparent cirrus clouds. The thermal channels clearly showed the upper layer cold cirrus cloud.

o The ground-based observations also included Jim Spinhirne's lidar developed by the DDF at Goddard. Thus Spinhirne had lidars on the ER-2, DC-8, and ground site simultaneously.

o The DC-8 lidar picked up the contrail of the ER-2 overhead. This remarkable feat shows the extremely good coordination between these two aircraft in both speed and location, as the field of the view of the lidar telescope is extremely small.

Many cloud climatological regimes were encountered during this six week-long experiment, thereby providing a very useful data set for further study. In addition to the case study described above, there were 2 research flights conducted over the eye of Typhoon Oliver.

2. CEPEX experiment

We spent the first week in Fiji for the Central Equatorial Pacific Experiment (CEPEX), based in Nadi, Fiji between March 7 and 12, 1993. During this time, one short ER-2 pilot qualification flight was conducted, which enabled me to assess the performance of the MAS and the data system in Nadi. The primary research objectives of CEPEX were centered on the water-vapor greenhouse effect and the role of tropical cirrus on radiation fluxes. The first research flight took off at the same time as our commercial airline departed. Before leaving, however, Liam Gumley showed 2 scientists in Prof. Ramanathan's group how to look at MAS data after each flight, thereby permitting a scientist to evaluate the scientific content of each flight. The ER-2 has now returned to Ames Research Center, having used all of their ~85 flight hours allocated for this experiment. I understand from Jim Huning and Tim Suttles (NASA Headquarters) and Jay Fein (NSF Headquarters) that all of the scientists were quite excited by this experiment. I have not yet received any data at Goddard from either deployment.

b. MODIS-related Instrumental Research

The 50-channel digitizer for the MAS work is progressing. From January to early April 1993, MAS performed successfully during the TOGA/COARE and CEPEX field experiments. We have found that the worst problems with MAS, which can be corrected, were the dewar hold time. The dewar on port 3 (3.725 microns) generally held for 3 to 4 hours and the one on port 2 (1.623-2.142 microns) for 4 to 5 hours after takeoff. After the dewars ran dry, these channels ceased to operate correctly; either saturated or became obscured by noise. The port 4 dewar (8.563-13.952 microns) had no problems. Don Smyrl of NASA Ames did pump down the dewars in the field but this did not seem to improve the hold times in dewars 2 and 3. Apparently, there was a leak in these two dewars, which were manufactured by the same contractor.

During two (flights 93-065 and 93-066) of the last four TOGA/COARE flights, problems were noticed in the navigation data recorded on the MAS Exabyte tape. Bad values for various navigation parameters would show up every now and again, and get worse as the flight progressed. Don Smyrl swapped Exabyte recorders and this seemed to eliminate the problem for the last TOGA/COARE flight (93-067). Also, the ER-2 INS (inertial navigation system) tape was physically damaged on the 93-066 flight. This problem can be overcome by obtaining time, latitude, longitude, heading, altitude, roll and pitch data from the Cloud Lidar group at GSFC.

Prior to the 93-066 flight (2/23/93 local time) the gain settings in channels 2, 3, and 4 were set to level 2x if takeoff was after 10:30 AM local time and 1x before 10:30 AM takeoff. This was because brighter convective clouds were being observed in the morning. For flights 93-066 and 93-067 (2/23-24/93 local takeoff) the gains in channels 2, 3, and 4 were set to 2s and the gain in channel 8 was changed from 4 to 8 to maximize the signal resolution. Based on the suggestion of Chris Moeller, an atmospheric transmittance code (modified from LOWTRAN-7) was run by Si-Chee Tsay in the field to examine the changes of channel 5 band center (from 1.83 microns to 1.88 microns). This shifted further into a water vapor absorption band which should enhance the ability to detect cirrus clouds at high altitudes. This change was effective in the CEPEX deployment.

The Stirling cycle near-infrared InSb detector subassembly for the Cloud Absorption Radiometer (CAR) has now arrived. It is larger than the previous one, which had additional tubes to the external high-pressure nitrogen gas supply. Therefore, some modification of the internal mounting structure is required to make the unit fit. This is in the process of being machined, installed, and will be tested to see if the detector/cooling assembly works as advertised, in which case we will no longer require a source of high-pressure nitrogen gas during field experiments. The Automatic Calibration System designed and installed by Max Strange is nearly operational. We have also received the uv-B filter and nearly all the dichroic beamsplitters, but have not yet received the new lenses that enable the uv radiation to transmit through the optical chain to the detector. Once all of these optical elements arrive in April or so, they will be installed and aligned. We have not yet worked out a technique to calibrate the CAR in the uv, but this will be explored by my optical technician (Nita Walsh) during April or May. CAR is scheduled to be sent to Wallops by July 1 for participating the SCAR-A (Sulfate, Clouds and Radiation) experiment.

c. MODIS-related Data Processing and Algorithm Study

Liam Gumley completed the first draft of the "MODIS Airborne Simulator Level-1B Data User's Guide." This document, together with the "MODIS Airborne Simulator Level-1 Processing User's Guide," were given to the MODIS SDST for review before publication as official MODIS reports. The first report describes the MAS instrument, the calibration and geolocation procedures, the Level-1B data contents, and instructions on how to use netCDF. The second one shows all the steps in the processing sequence, and includes sample command syntax, program
descriptions, a glossary of terms, and MAS specifications and data formats.
Also, the MAS Level-1 Processing System source code was packaged and handed over to the new maintainer (Paul Hubanks, MODIS SDST). Both the PC (MSDOS) and Iris/Indigo (Unix) versions were delivered along with compilation instructions and scripts.

Tom Arnold has nearly completed the first draft of the "MAS visible and near infrared calibration: 1992 ASTEX field experiment" for review and publication. An intercomparison of the MAS and AVIRIS instruments during FIRE Cirrus II was conducted to access the calibration accuracy of the MAS visible/near-IR channels against an instrument with known calibration accuracy (AVIRIS). Data from December 5, 1991 were examined by Liam Gumley. Initial results showed a problem with the calibration of the MAS channels 5 and 6 due to the temperature dependent gain correction applied to MAS data. Along a similar line, a comparison of data from the MAS and HIS is underway to establish the calibration accuracy of the MAS IR channels. Further work is underway to more fully assess the overall calibration accuracy of the MAS, and to understand the problem that has been discovered.

Ward Meyer has processed some of the LEADEX (Lead Experiment, conducted in the Beaufort Sea, Alaska during April 1992) surface bidirectional reflectivity of multi-year snow/ice and snow over tundra, obtained by the CAR. Polar contour plots for a new set of angular distribution cases were processed through program CARASPLT, Spyglass (Transform and Format) and MacDraw Pro. Si-Chee Tsay has analyzed the angular distribution of surface bidirectional reflection functions (flight 1539) of CAR channels 1, 6, 7, and 9 (0.5, 1.22, 1.27 and 1.64 microns), including a few specific sensor viewing planes for detail structure. The striking features in these polar plots are: the blind (specular reflection) and hot (direct backscattering) spots around the principal plane (0 - 180 degree azimuthal plane); the darkest spot around 110 degrees azimuthal plane; nearly isotropic scattering (regardless of the horizontal inhomogeneity introduced by the surface snow / ice ridges and valleys) at all viewing angles except near the forward (larger than about 40 degrees nadir) and the backward (larger than 60 degrees nadir) portions.

Ward Meyer and Dave Augustine (a new member of my group) worked closely on our archive system of raw and processed aircraft data. Da-Sheng Feng and Ward Meyer continued to work on the CAR diffusion domain data from the FIRE 1987 flights. Da-Sheng Feng has completed the analyses for Flight 1301 which contained seven flight sections in the cloud diffusion domains and more than 100 good measurements, including two ship track cases. We are working on the statistical relationship between cloud microphysical and radiative properties from these diffusion domain data.

d. MODIS-related Services

Meetings:

1. attended the first SeaWiFS Science User's Group meeting in Annapolis, Maryland, on January 19 and spent nearly 1 hour discussing various scenarios for convergence of the NOAA afternoon polar orbiter series with the EOS PM series (PM-2 and PM-3) with Dr. Kathryn Sullivan (Chief Scientist of NOAA).

2. began working with the new EOS Color Project Scientist and the EOS Chemistry and Special Flights Project to begin to better define the EOS Color mission, aimed at being used to derive ocean color and phytoplankton pigment concentrations in concert with MODIS, prior to the launch of EOS PM-1 (thereby providing 2 MODIS sensors in orbit).

3. worked closely with Ghassem Asrar in updating the Science Reference Handbook, which was published towards the end of March.

4. served as the flight scientist for the NASA ER-2 and mission scientist for the DC-8 aircraft in a coordinated multi-aircraft radiation flight during TOGA / COARE. This radiation mission was very successful. Many optical phenomena in the atmosphere, such as sun dogs / pillars and glory were observed and measured by MAS and other instruments.

5. chaired the MODIS Science Team Meeting for the Atmospheric Group, held on March 24-26 at the Holiday Inn, Greenbelt, MD.

6. co-chaired the EOS Investigators' Working Group Meeting at the Greenbelt Marriott, Greenbelt, MD on March 29-April 1.

Seminars:

1. gave a 1 hour seminar at Hughes Information Technology Center, the EOSDIS Core System Contractors, on EOS.

III. Anticipated Activities During the Next Quarter

a. attend the SCAR-A (1993-Wallops Island) and SCAR-B (1994-Brazil) Mission Planning Workshop, to be held on April 27-28 at the Holiday Inn, Greenbelt, MD;

b. attend the Workshop on Remote Sensing of Aerosols by MODIS and other EOS instruments, to be held on May 17-18 at Martin's Crosswinds, Greenbelt, MD;

c. attend the AGU Spring Meeting, to be held on May 24-28 at the Inner Harbor Marriott, Baltimore, MD for presenting papers and participating ASTEX Working Group Meeting;

d. attend the CERES IDS Review and Science Team Meeting, to be held on June 8-11 at the Fort Magruder Inn, Williamsburg, VA;

e. continue the effort of refining the data analysis algorithm and re-examine more carefully the retrieval of cloud optical and microphysical properties by using data gathered from MAS;

f. continue to analyze the bidirectional reflectance measurements obtained during the Kuwait Oil Fire, LEADEX and ASTEX experiments;

e. start to analyze data sets obtained from the TOGA / COARE and CEPEX field campaigns.

IV. Problems / Corrective Actions

No problems that we are aware of at this time.

V. Publications

Harshvardhan, and M. D. King, 1993: Comparative accuracy of diffuse radiative properties computed using selected multiple scattering approximations. J. Atmos. Sci., 50, 247-259.

King, M. D., L. F. Radke and P. V. Hobbs, 1993: Optical properties of marine stratocumulus clouds modified by ships. J. Geophys. Res., 98, 2729-2739.

King, M. D., and S. C. Tsay, 1993: Radiative and microphysical properties of marine stratocumulus clouds: Results from ASTEX. To be presented at the AGU Spring Meeting.

Tsay, S. C., and M. D. King, 1993: Measurements of bidirectional reflectivity over snow, ice, and other types of surfaces. To be presented at the AGU Spring Meeting.

Gumley, L. E., M. D. King, S. C. Tsay, and B.C. Gao, 1993: Intercomparison of MAS, AVIRIS, and HIS data from FIRE Cirrus II. Submitted to FIRE Cirrus Science Conference.